Chemical Reactions

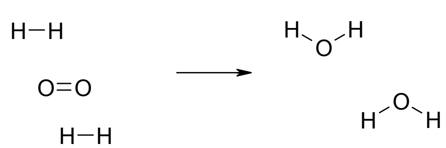
CHM 1032C

Chemical Equations

Chemical change involves a reorganization of the atoms in one or more substances.

The **Hindenburg** Reaction

- Reactants are on left, products to the right.
- Arrow indicates the change



A chemical equation

- Notice that the formula for the molecules is unchanged.
- To indicate that more than one molecule is required, use coefficients (shown in blue).
- The equation is balanced.

$$2\ H_2 + O_2 \rightarrow 2\ H_2O$$

The Rules

- Change only the coefficients to balance the chemical equation.
- Balance one element at a time.
- Continue to balance the other elements in the same manner.
- Adjust coefficients to the lowest whole number common multiple.
- Check your answers.

Example

$$FeI_2 + \quad Cl_2 \rightarrow \quad FeCl_3 + \quad I_2$$

Balancing Combustion Reactions
Fuel + O_2 → CO_2 + H_2O

- Balance carbon first
- Hydrogen second
- Oxygen last
- Multiply by 2 if you need to.

___ C_3H_8 + ___ O_2 → ___ CO_2 + ___ H_2O

More Balancing and Things to Avoid

___ C_4H_{10} + ___ O_2 → ___ CO_2 + ___ H_2O

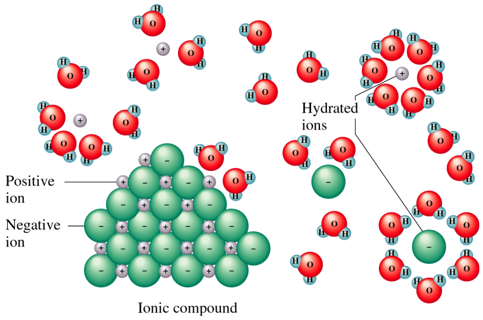
- Coefficients should always have the lowest whole number ratio.
- Never Change the subscripts. 8 CO_2 is not the same as C_8O_{16}.

___ C_8H_{16} + ___ O_2 → ___ CO_2 + ___ H_2O

Reactions in Water (Aqueous)

- In water, when ionic compounds dissolve, they dissociate into their anions and cations.
- It is the polarity of water that allows them to do this.
- Some compounds are soluble and others are not.
- Water is very stable

Ionic compounds in water



Describing phases

- (s) solid
- (l) liquid
- (g) gas
- (aq) aqueous (dissolved in water)

Reaction Types

- Combination
- Decomposition
- Single Replacement
- Double Replacement
- *Combustion*

This is not a comprehensive list!

Driving Forces

- Transfer of electrons. (Also called Redox or oxidation/reduction reactions.) *Charges change*
- Formation of a solid
- Formation of a gas
- Formation of water

Aqueous Ionic Reactions

- Some key terms that are necessary when dealing with aqueous ionic reactions are:
  - 1) A solution is a mixture in which one substance called the solute is uniformly dispersed in another substance called a solvent.
  - 2) Solvation - the process of a solvent dissolving a solute.
  - 3) Dissociation - where cation and anion separate from each other.
  - 4) Spectator ions - ions that do not participate in a reaction.

Solubility Rules

1. All compounds containing Na^+, K^+, or NH_4^+ ions are soluble in water.

2. All nitrates (NO_3^-) are soluble in water.

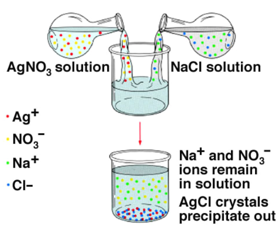
3. Most chlorides (Cl^-), and sulfates (SO_4^{2-}) are soluble. Some important exceptions are silver chloride (AgCl), barium sulfate ($BaSO_4$), and lead sulfate ($PbSO_4$) which are insoluble.

4. Most carbonates (CO_3^{2-}), phosphates (PO_4^{3-}), sulfides (S^{2-}), and hydroxides (OH^-) are insoluble in water. Important exceptions are those of Na^+, K^+, or NH_4^+, as well as barium hydroxide, $Ba(OH)_2$.

Double Replacement

- Pattern: AB + CD → AD + CB
- Water is usually the solvent
- Basically the anions switch.
- Driving force is the formation of a solid (precipitation reactions), formation of water (acid-base reactions/ neutralization reactions) or formation of a gas.

$AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$



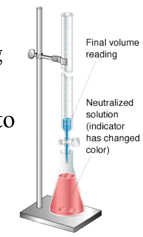
Driving Force: Formation of a Solid

Steps in examining a reaction

1. Identify the type of reaction.
   - identify A, B, C, D
2. Find the correct products *(use switchero rule)*
   - Add phases. (Use solubility rules)
3. Balance the equation.

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

- The driving force is the formation of water.
- Note that it is hard to see anything happening
- Traditionally we use an indicator to watch the disappearance of OH^-.
- This reaction also produces heat



$HCl_{(aq)} + NaHCO_{3(aq)} \rightarrow H_2O_{(l)} + CO_{2\,(g)} + NaCl_{(aq)}$

$HCl_{(aq)} + NaHCO_{3(aq)} \rightarrow H_2CO_{3(aq)} + NaCl_{(aq)}$

$\hookrightarrow H_2O_{(l)} + CO_{2\,(g)}$

Driving force is the formation of gas and the formation of water

You will have to memorize that H_2CO_3 produces $H_2O_{(l)} + CO_{2\,(g)}$

Combination Reaction

- Pattern: A + B → AB
- Can be recognized because there is only one product.
- Example: $2\ Mg + O_2 \rightarrow 2\ MgO$
- Driving force is often the transfer of electrons.

Oxidation-Reduction

- Oxidation-Reduction reactions, often called 'Redox Reactions', are another way to classify chemical reactions.
- Redox reactions are simply classified as reactions where the oxidation state (charge) of the species involved changes during the chemical reaction.

'Redox'

- The term 'Redox' comes from the concatenation of the terms "Oxidation" and "Reduction".
- Redox reaction are characterized by *Electron Transfer* between an electron donor and electron acceptor. Charges change.

Example: Combination

- For the following reaction determine which substance gets oxidized and which substance gets reduced.
- Loss of Electrons is Oxidation
- Gain of Electrons is Reduction
- LEO the lion says GER
- $2\ Mg + O_2 \rightarrow 2\ MgO$

Example

- Use your knowledge of the periodic table to determine the oxidation states of each of the species.
  - Remember that species in their 'natural' state (uncombined) have oxidation numbers of zero.

Therefore:

$$2\ Mg^{0} + O_2^{0} \rightarrow 2\ Mg^{2+}O^{2-}$$

Keys for Combination Reactions

- If there is one product, it is a combination reaction.
- Most combination reactions are Redox Reactions, look for the charge changing.
- Other examples of Combination reactions:
  - $4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$ ***(rust!)***
  - $2\ H_2 + O_2 \rightarrow 2\ H_2O$

Decomposition Reactions

- Pattern: $AB \rightarrow A + B$
- Can be recognized because there is only one reactant.
- Driving force is often the transfer of electrons.
- Example: $2\ H_2O \rightarrow 2\ H_2 + O_2$
- Example: $2\ H_2O_2 \rightarrow 2\ H_2O + O_2$

  (Hydrogen peroxide)

Single Replacement

- Pattern: A + BC → B + AC
- A goes from elemental state to ionic state.
- B goes from ionic state to elemental state
- A is oxidized, B is reduced
- Occurs because some elements are more stable in the elemental state than others. The activity series shows the more stable elements on the bottom.

$Al_{(S)} + CuSO_{4(aq)} \rightarrow Cu_{(s)} + Al_2(SO_4)_{3(aq)}$

Activity Series

Metal	Oxidation reaction	
Potassium	$K \rightarrow K^+ + e^-$	most reactive/least stable
Sodium	$Na \rightarrow Na^+ + e^-$	
Magnesium	$Mg \rightarrow Mg^{2+} + 2e^-$	
Aluminum	$Al \rightarrow Al^{3+} + 3e^-$	
Zinc	$Zn \rightarrow Zn^{2+} + 2e^-$	
Iron	$Fe \rightarrow Fe^{2+} + 2e^-$	
Hydrogen	$H_2 \rightarrow 2H^+ + 2e^-$	
Copper	$Cu \rightarrow Cu^{2+} + 2e^-$	
Silver	$Ag \rightarrow Ag^+ + e^-$	
Mercury	$Hg \rightarrow Hg^{2+} + 2e^-$	
Platinum	$Pt \rightarrow Pt^{2+} + 2e^-$	least reactive/most stable
Gold	$Au \rightarrow Au^{3+} + 3e^-$	

All metals above hydrogen will react with acids.

- $Mg_{(s)} + 2\ HCl_{(aq)} \rightarrow H_{2(g)} + MgCl_{2(aq)}$
- Magnesium is being oxidized:
  - $Mg \rightarrow Mg^{2+} + 2e^-$
- Hydrogen is being reduced:
  - $2H^+ + 2e^- \rightarrow H_2$

Organic Chemistry

- The chemistry of carbon based compounds
- Organic compounds are based on a hydrocarbon backbone.
- In organic chemistry: **Oxidation** is an increase in the number of bonds to oxygen or a decrease in the number of bonds to hydrogen.
- **Reduction** is a decrease in the number of bonds to oxygen or an increase in the number of bonds to hydrogen.

Oxidations & Reduction

- $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$
- http://img.medscape.com/fullsize/migrated/545/119/apt545119.fig2.gif